INFLUENCE OF TORREFACTION TREATMENT ON WOOD POWDER PROPERTIES

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ABSTRACT: Torrefaction is a thermal pretreatment of lignocellulosic biomass before gazification. This mild form of pyrolysis, carried out at temperatures between 200 and 300 °C, changes the physical and chemical properties of the material. In particular, it improves the feedstocks homogenization, enhances the fluidization ability and makes the grinding easier.
Our project deals with the study of the effects of the combined torrefaction and grinding processes on (*i*) the main particle behavior: anhydrous weight loss (AWL), grindability, particle size distribution (*ii*) and the main powder behavior: bulk densities, flowability and compressibility. The studied parameters are (*i*) the species of the biomass (spruce and beech) (*ii*) the torrefaction temperature (*iii*) and the sieving grid size of the used knife mill (0.12 and 0.5 mm). The characterization of the particles and powders is performed using the following techniques: optical microscope and powder rheometer. The rheological behaviours of spruce torrefied at different temperatures and ground at different grid sizes are compared. It is shown that spruce torrefied at 240 °C and ground at 0.5 mm (S240/0.5) has rheological properties not as good as S240/0.12 and S300/0.5 that seem to have similar characteristics. Finally, further experiments are necessary to obtain a better morphological and rheological particle characterization.
Keywords: biomass to liquid (BtL), lignocellulosic sources, wood, torrefaction, analysis, characterization.

1 INTRODUCTION

Thermal processes are often used to transform woody biomass into gaseous or liquid fuels (BTL process [1]). High requirements on produced syngas purity call for gas cleaning methods or for gazification methods producing relatively clean syngas (CO, CH_4, H_2), particularly with low content of tar (acids, aldehydes, naphtalenes, phenols, …, [2-3]). One way to reduce the tar products is to operate the thermochemical conversion reactor at high temperature (> 1000°C) and high pressure ensuring a biomass residence time below a few seconds [4]. These operating conditions can be reached using dedicated gas-particle technologies such as fast circulating fluidized beds or entrained flow gasifiers [5]. For such technologies, ground torrefied wood powder is one of the forms of biomass that is most suitable for feeding.

Torrefaction is a mild form of pyrolysis carried out at temperatures between 200 and 300 °C. It improves the feedstocks homogenization and makes the grinding easier [6] due to the changes on its physical and chemical properties [7].

For instance, previous studies have shown that, for an anhydrous weight loss (AWL) below ~8% (which corresponds to torrefaction temperature below 240 °C for beech and 260 °C for spruce), the effect of the torrefaction on the grinding energy is very high [8]. Over 8%, the effect of the torrefaction is lower. At an AWL around 28% (which corresponds to torrefaction temperature about 280 °C for beech and 300 °C for spruce), the grinding energy was reduced by 93%. Also it was observed that for the same temperature of torrefaction, beech AWL was higher than spruce one [9], which may be explained by the difference of the chemical composition of the two biomasses in terms of hemicelluloses content [10].

Our project consists in an experimental study of the coupled effects of torrefaction and grinding [8-9] on the particles morphology and powder behaviour. All the experimental data will be correlated in order to predict the optimum torrefaction and grinding conditions for transport and fluidization purposes.

2 MATERIALS AND METHODS

2.1 Pretreatment procedure

Beech and spruce chips were torrefied in a hot batch rotating pilot kiln [9] at different conditions in terms of temperature and residence time. For each torrefaction condition, the temperature of the moving chips was continuously controlled using thermocouples placed in the vicinity of the rotating kiln. The final anhydrous weight loss of each batch of biomass was measured. The torrefied biomasses were then ground and sieved with a knife mill. The energy required for grinding particles below 200 µm was measured (Fig. 1).

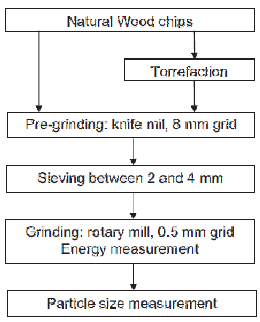

Figure 1: Scheme of the experimental procedure.

2.2 Morphological analysis procedure

A tool was then designed to homogeneously distribute the particles on a plate to observe them by an optical microscope. A complex image analysis procedure was developed to obtain a representative statistical characterization (particle size, shape distribution, surface state) [11]. The ground torrefied material was finally analysed by several techniques to determine its powder rheological properties and compressibility (FT4®

rheometer, Flodex®, Autotap®) [12-13].

3 RESULTS AND DISCUSSION

3.1 Particles morphological characterization

First results obtained by optical microscopy on non-treated spruce ground with a 0.5 mm sieving grid (NS/0.5) show that the particle size distribution is wide with an average diameter mode at around 4 µm (Fig. 2, Fig. 3).

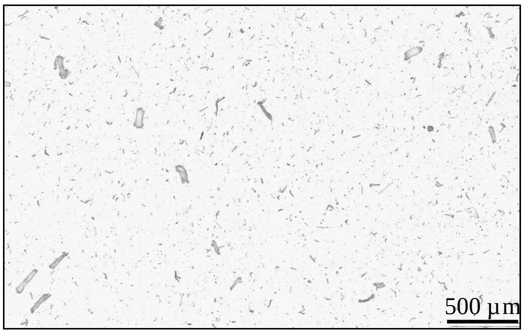

Figure 2: Sample of NS/0.5 (optical microscopy).

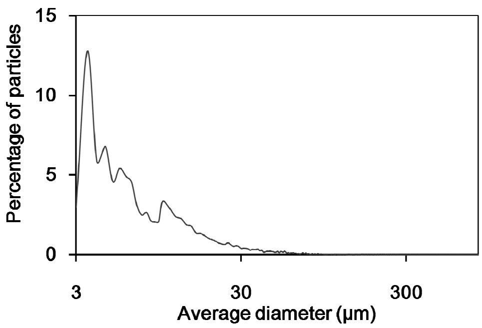

Figure 3: Particle size distribution for NS/0.5.

3.2 Powders rheological properties

On the one hand, the rheometry technique and the Flodex® method show (Fig. 4, Table I; Table II) that, when torrefied and ground at 240 °C/0.12 mm, the spruce powder has the same behaviour as at 300 °C/0.5 mm. At 240 °C/0.5 mm, the powder flowability is much lower. Thus, the biomass flowability is increased when there is either a fine grinding coupled with low temperature torrefaction or a coarse grinding coupled with high temperature torrefaction. The comparison with the behaviour of a powder of mono-dispersed rigid spherical glass particles (GB 0.29 mm) shows the impact of the shape and surface state of the particles on their flowability (Table II).

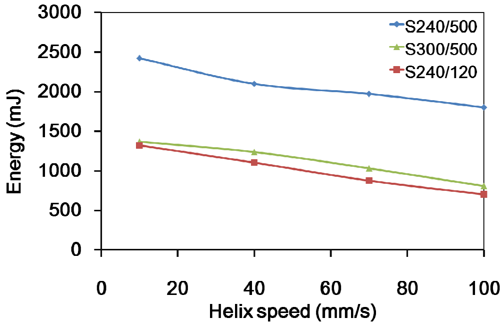

Figure 4: Variation of consumed energy in function of the helix speed and the type of wood powder.

Table I: Flow rate index of wood powders S240/0.12; S240/0.5 and S300/0.5.

Type of wood powder	S240/0.12	S240/0.5	S300/0.5
CBD (g/mL)	1.86	1.73	1.40
FRI	0.32	0.28	0.16

Table II: Comparison of the flowability of several types of wood powder.

Type of wood powder	Spruce S240/0.12	S240/0.5	S300/0.5	Glass beads GB0.29mm
Min. d.[a] (mm)	24	34	26	2

[a] minimum diameter required for the powder to freely fall through a hole

On the other hand, compressibility measurements done by Autotap® seems to show a better flowability for spruce torrefied at 240°C (S240/0.12 or S240/0.5) than for spruce torrefied at 300°C (S300/0.5). This reverse tendency compared to the previous one obtained by FT4® rheometer and Flodex® methods strengthens the interest to use several techniques to better understand woody powders behaviour.

4 CONCLUSION

Morphological characterization by optical microscopy will be extended to different types of wood powder. More information could be obtained about particle size and shape, its sphericity and surface state. Regarding rheological behaviours, spruce torrefied at different temperatures and ground at different grid sizes were compared. It seemed that spruce torrefied at 240 °C and ground at 240 °C/0.12 mm (S240/0.12) and spruce torrefied and ground at 300 °C/0.5 mm (S300/0.5) have better rheological properties than spruce torrefied and ground at 240 °C/0.5 mm (S240/0.5). Further experiments such as shear and aeration tests could be an asset to obtain more rheological properties. We expect to establish soon a correlation between all results in order to predict the optimum torrefaction and grinding conditions for transport and fluidization purposes.

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